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Maxillary sinus floor elevation surgery

Timmenga, Nicolaas Marius

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Chapter 6

Effects of Maxillary Sinus Floor Elevation Surgery on Maxillary Sinus Physiology

Nicolaas M. Timmenga MD DDS¹, Gerry M. Raghoobar MD DDS PhD¹

Robert S.B. Liem PhD², Ranny van Weissenbruch MD PhD³

Willem Manson MD PhD⁴, Boudewijn Stegenga DDS MSc PhD¹

Arjan Vissink MD DDS PhD¹

¹Department of Oral and Maxillofacial Surgery and Maxillofacial prosthodontics

²Department of Cell Biology, Section Electron Microscopy

³Department of Otorhinolaryngology

⁴Department of Medical Microbiology

^{1, 3, 4}Groningen University Hospital

²University of Groningen

The Netherlands

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Abstract

In a prospective study, the effects of elevation surgery of the maxillary sinus floor on maxillary sinus physiology were assessed. Seventeen consecutive patients without preoperative anamnestic, clinical and radiological signs of maxillary sinusitis underwent sinus floor elevation surgery with iliac crest bone grafts. All patients were subjected to unilateral endoscopic examination of the maxillary sinus, taking of a biopsy specimen from the sinus floor mucosa, and collection of a sinus lavage-fluid aspirate. This triad of evaluations was performed immediately preceding the elevation procedure, and three months (at implant insertion) and nine months (at uncovering of implants) postoperatively. All procedures were performed under general anaesthesia. Preoperatively, three out of 17 patients showed pre-existing mucosal pathology endoscopically, while the three and nine months results revealed the presence of mucosal pathology in four and two patients, respectively. The three months microbiological evaluation showed a significant increase of cultures with bacterial growth, while the nine months culture results were comparable to the preoperative status of the maxillary sinus. Morphologically, neither fibrosis nor an altered inflammatory response or thickening of the epithelium and lamina propria was observed postoperatively. The number of goblet cells in the epithelial layer was increased. From this study it is concluded that the effect of maxillary sinus floor elevation surgery with autogenous bone grafts does not appear to have clinical consequences in patients without signs of pre-existing maxillary sinusitis.

Introduction

Maxillary sinus floor elevation surgery with autogenous bone grafts has proven to be a reliable method to enable insertion of endosseous implants to support an upper denture in patients with a severely resorbed maxilla or who have functional denture problems because of other reasons (Timmenga et al. 1997; Van den Bergh et al. 2000; Ten Bruggenkate and Van den Bergh 2000; Raghoobar et al. 1993, 2001). Maxillary sinusitis after this procedure was considered to be the major drawback, although many results were based on non-clear criteria for examination and diagnosis of maxillary sinusitis (Doud Galli et al. 2001). When using general accepted Ear Nose and Throat (ENT)-criteria for diagnosing sinusitis, however, development of post elevation chronic maxillary sinusitis has been reported to occur in 1.3% of the patients who underwent such a procedure (Timmenga et al. 2001).

Although not many patients develop maxillary sinus pathology related complaints after sinus floor elevation surgery, this procedure carries the inherent risk of compromising sinus physiology. It is generally assumed that the maxillary sinus physiology is affected by the altered anatomy i.e. the lifted sinus floor in combination with a bulging or injured subsurface of the lifted sinus mucosa. Mucosal swelling may also lead to reduction of the patency of the ostio-meatal unit. This unit plays a key-role in the development of sinusitis, viz. by impairment of the mucociliary cleansing system (Bertrand and Eloy 1992). If the maxillary sinus is (partly) filled up by haematoma or seroma and/or the patency of the maxillary ostium is reduced, maxillary sinusitis might develop compromising the success of the grafting procedure.

In order to gain objective data on possible sinus pathology following sinus floor elevation surgery with iliac crest bone grafts, a prospective, endoscopic, microbiologic and morphologic examination of the maxillary sinus was carried out in patients without preoperative signs of maxillary sinusitis. Direct observation of the ostio-meatal unit and the mucosal lining of the maxillary sinus are of great importance in the evaluation of sinus (clearance) impairment and in diagnosing maxillary sinusitis. It also facilitates other diagnostic means like biopsy, cytological smears and cultures (Pfeiderer et al. 1986; Bavbek et al. 1997).

Materials and Methods

Patients

Seventeen consecutive patients (11 women, 6 men), with a mean age at time of surgery of 53 ± 15 years (range 22-73), were included in this prospective study. All patients were referred to the department of oral and maxillofacial surgery of the Groningen University Hospital because of poor retention of the (partial) upper denture related to severe resorption of the posterior maxilla. The patients were examined by two experienced prosthodontists and two experienced oral and maxillofacial surgeons. The maxilla was edentulous in 15 patients, and partially dentate in two patients. In all patients sinus floor elevation surgery with autogenous bone grafts was indicated. Surgery and prosthodontic aftercare were performed within the same clinic. Informed consent was obtained from all patients.

As part of the inclusion criteria, all patients were preoperatively subjected to anamnestic screening for sinus clearance compromising factors using a standardised questionnaire. Clinical examination of the patients was performed by rhinoscopy to examine the condition of the nasal mucosa, while nasendoscopy was performed for inspection of the ostio-meatal unit. Patients were considered to suffer from maxillary sinusitis in case of mucosal redness and oedema of the nasal mucosa, and presence of mucopurulent discharge around the maxillary ostium (Yonkers 1992). Although CT-scanning would have provided more detailed information, conventional radiography (Waters' projection) was used in this study. The potential risk of damaging eyes of healthy humans by the high radiation dose from CT-scanning was found to be a conclusive ethical objection. Furthermore, it has been shown that a combination of nasoendoscopy and Waters' projection is a generally accepted diagnostic procedure to rule out structural sinus clearance impairment despite a sensitivity of Waters' projection for diagnosing maxillary sinusitis of 85% (Timmenga et al. 2002).

Patients with a history of a disturbed clearance function of the maxillary sinus were included only in case of absence of preoperative clinical and radiographic signs of actual sinusitis. In case of other medical compromising factors, e.g. diabetes mellitus, internal screening and regulation were performed preoperatively.

Experimental design

In all patients, sinus floor elevation surgery was performed bilaterally with iliac crest bone grafts as was described by Raghoobar et al. in 1993 and 2001. Three months post-elevation, implants were inserted followed by uncovering of the implants six months later. Prior to the elevation procedure, implantation and uncovering procedure unilaterally endoscopic inspection of the maxillary sinus was performed with a rigid nasal endoscopic optic (Figure 1). Subsequently, a biopsy of the mucosal lining of the maxillary sinus floor was taken with a small forceps (Figure 1a) via the introduced cannula, followed by aspiration of sinus lavage-fluid using a disposable mucus suction set (Figure 1b) to collect a microbiological sample. The biopsy was taken first to prevent ciliary damage by manipulating with the suction cannula in the antral cavity. The cannula is directed to the lateral-caudal sinus wall by introducing the trocar via the inferior meatus into the maxillary sinus (Figure 1). All biopsies were taken from that small area of the latero-caudal antral wall. Hardly any bleeding occurred which made a reliable microbiological sampling procedure possible in all cases.

Endoscopy

Under general anaesthesia, after decongestion of the nasal cavity, endoscopy of the middle meatus with special emphasis on the infundibular area was performed (Figure 1). The examination side was randomised for the first inspection, while the same side was used again for the three and nine months evaluations. After medialisation of the inferior turbinate, a trocar was inserted via the inferior meatus into the antral cavity. Endoscopic examination was performed with a rigid endoscopic optic (30 degree Storz Germany), linked to a Panasonic CCD camera, and Sony video printer. All endoscopic procedures were performed by the same experienced ENT-surgeon.

Assessment of the mucosal aspect of the elevation area of the maxillary sinus was based on sinoscopic assessment, as proposed by Petruson (1982) and modified by Westergren et al. (1998). A normal aspect of the sinus mucosa showing its delicate vascular patterns, without any sign of discharge or swelling was scored as a grade 0. A hyperaemic aspect of the sinus mucosa was scored as grade 1, mucosal swelling as grade 2, and existence of discharge as grade 3. Grade 4 was scored in case the antral mucosa showed severe inflammation with polypsis.

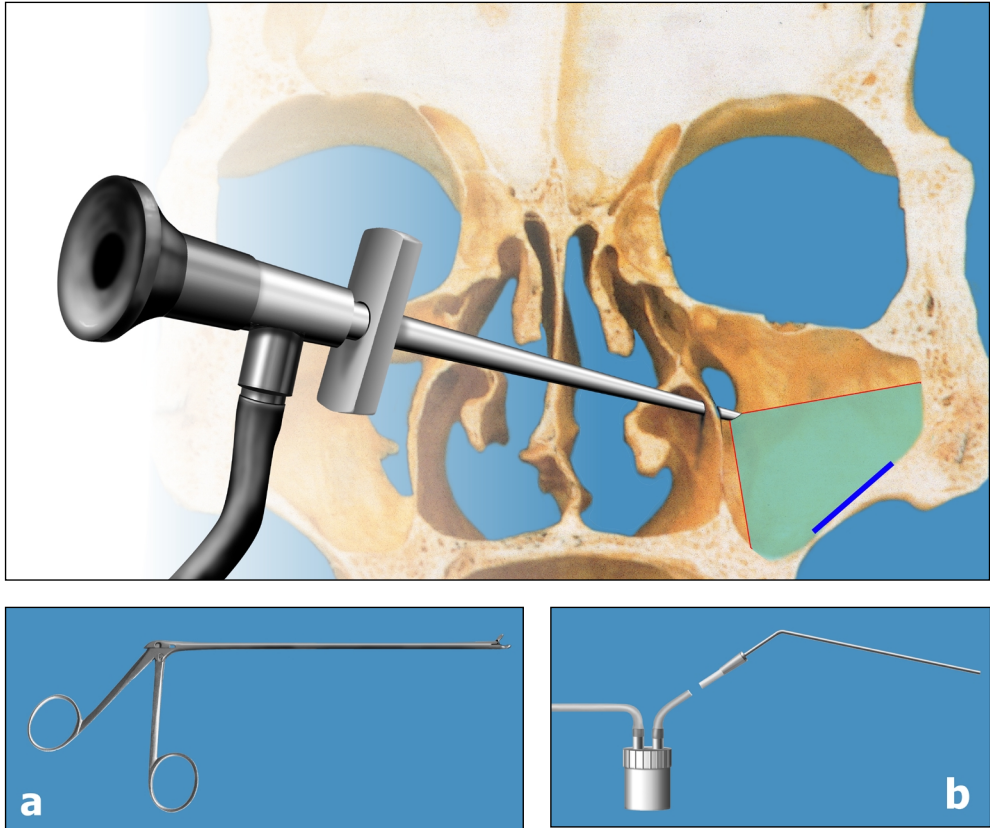


Figure 1 *Via the infra-meatal fossa a trocar is inserted into the antral cavity. A 30-degree rigid endoscope is introduced through the cannula. Its viewing field is highlighted, but can be adjusted by rotating the endoscope. After inspection a small forceps biopsy specimen was taken from the latero-caudal antral wall (blue line), for histological examination and sinus lavage-fluid was aspirated with a suction set for microbiological examination, both via the cannula.*
a Biopsy forceps, **b** Suction set.

Surgery and prosthodontics

In all patients bilateral sinus floor elevation procedures were performed with iliac crest (blocks and particulate) bone grafts according to the procedure described (Raghoobar et al. 1993, 2001). The grafts were harvested from the superior anterior medial part of the iliac crest. Block grafts were placed on the floor of the elevated sinus membrane and used as a buccal onlay if the width of the alveolar crest was too small. The remaining spaces around the block grafts were filled with particulate bone. Before harvesting the bone grafts, all patients received anti-microbial

prophylaxis (cephradine 1 g, 3 times daily), starting one hour preoperatively (intravenously) and continued orally for 48 hours after surgery. Postoperatively, the patients received a 0.2% chlorhexidine mouth rinse (1 min, 5 times daily) for two weeks. After three months, titanium implants (Brånemark, Nobel Biocare, Göteborg, Sweden) were inserted using a surgical template. Six months after insertion the implants were uncovered, the oral mucosa was thinned if applicable and the abutments were connected. The patients were provided with implant supported overdentures (n=15) or partial bridges (n=2).

Morphology

When taking a biopsy of ciliated mucosa, one is running a risk to mechanical damage of tissue structures, e.g. ciliae. Ciliary damage is a common finding when performing histomorphological examination of maxillary mucosal biopsy specimen of patients with sinusitis (Hinni et al. 1992; Westrin et al. 1992). A difference between mechanically damaged ciliae and ciliary damage caused by sinusitis can be made by precise light and electron microscopical examination of the antral epithelium and submucosa. All preoperatively obtained biopsies were examined with special attention to iatrogenic damage caused by the biopsy technique. The outcome was an undisturbed ciliated aspect in all cases. Probably the bulky aspect of the mucosal sample and the performance of the sinus lavage after taking the biopsy have minimised the risk on iatrogenic ciliary damage.

Endoscopically obtained biopsies were rinsed in saline and placed into a fixative containing 2% glutaraldehyde buffered with 0.1 M sodium cacodylate buffer (pH 7.4). The tissue specimens were then subdivided into two approximately equal samples. One sample was used for scanning electron microscopy (SEM) and the other sample was used for light microscopy (LM) as well as transmission electron microscopy (TEM).

For SEM, the samples were additionally fixed with 1% osmium tetroxide for one h, followed by dehydration in graded concentrations of ethanol and critical point dried in liquid CO₂. The samples were then glued onto aluminium stubs with fast curing epoxy resin, sputter coated with gold/palladium in a Balzer Union sputtering device (Balzer Union, Fürstentum Lichtenstein) and examined in a Jeol Fe-SEM 6301-F scanning electron microscope (Jeol Ltd., Tokyo, Japan), operated at an accelerating voltage of 2 kV. For LM and TEM, the tissue samples were postfixed in a mixture of 1% osmium tetroxide/K₄FeCN₆ for one h, dehydrated in graded series of ethanol and propylene-oxide and embedded in Epon (Serva Feinbiochemica GmbH., Heidelberg, Germany). From all blocks, four midsagittal

semithin sections, each 1 μm thick, were prepared using a diamond histo-knife and a Reichert-Jung OMU4 ultra-microtome (Vienna, Austria). The semithin sections were stained with toluidin blue, and evaluated with LM for morphological analysis, and photomicrographed using a Zeiss photomicroscope (Zeiss, Oberkochen Germany).

For TEM analysis, ultrathin (40-60 nm) sections adjacent to the semithin sections were cut, stained with uranyl acetate and lead citrate, and examined with a Philips CM-100 transmission electron microscope.

Quantitative or semi-quantitative LM assessment of the morphological aspect of the endoscopically obtained biopsy specimens was based on histologic criteria described in literature (Ham and Cormack 1987). With a High Power Field (HPF) magnification (400x), using ocular 10x and objective 40x, maxillary mucosal biopsy specimens were evaluated. In a randomized order an experienced histologist and a pathologist independently examined all slides. Morphologic assessment of the epithelium included its thickness scored as 'normal' (2-5 cell layers), or 'thickened' (5 or more cell layers), and the ciliated aspect of the epithelium was scored as 'normal' or 'abnormal' (i.e. absence or damaged cilia). The number of goblet cells per 100 epithelial cells (goblet-cell ratio) was counted. Counting the number of inflammatory cells per HPF (including polymorphonuclear cells PMN's), lymphocytes, plasma cells and mast cells assessed the inflammatory response of the epithelial cell layer. The basal lamina was assessed with regard to its thickness, ('not visible' or 'clearly visible'). The connective tissue aspect of the submucosa (lamina propria) was scored as 'areolar connective tissue', 'dense connective tissue' or 'presence of fibrosis'. Counting the number of inflammatory cells per HPF (including PMN's, lymphocytes, plasma cells and mast cells) assessed its inflammatory response. The presence of blood vessels (vascular response) and seromucous glands were scored as 'absent', 'a few' or 'many'.

Microbiology

In clinical (ENT)-practice, microbiological examination is generally performed by antral needle aspiration (antral tap) or sinus endoscopy via the nasal inferior meatus (Van Cauwenberge and Ingels 1996; Vogan et al. 2000). Antral cultures can be obtained via the canine fossa as well, but such a procedure has the inherent risk of oral contamination as well as that long lasting discomfort has been reported after this procedure (Bernal-Sprekelsen et al. 1991; Rong San Jiang et al. 1999). As endoscopy was part of our study it was chosen to obtain microbiological samples by endoscopic sinus lavage.

After randomised unilateral inspection of the maxillary sinus and taking the mucosal biopsy, the content of a 5 mL syringe, filled with saline 0.9%, was introduced into the sinus via the cannula. Subsequently, the lavage fluid was collected using a sterile disposable mucus suction set (International Medical Products 990305, Zutphen, The Netherlands) introduced into the sinus via the same cannula. Microbiologic sampling was performed according to the procedure described by Isenberg (1992). Culturing of the samples was carried out according to a standardised method (Murray et al. 1999). After collection of maxillary sinus fluids in the suction set container, the specimen arrived at the department of medical microbiology within half an hour. First, the specimen was centrifuged for 10 seconds, and plated onto 5% blood sheep- and chocolate-agar, for incubation in 10% CO₂ and sabouraud- and MacConkey-3-agar for incubation in ambient air. All agar plates were incubated for 48 hours. For anaerobic culturing, the specimen were inoculated onto brucella blood-, bacteroides-bile-, kanamycin-vancomycin laked blood- and phenylethyl alcohol agar and incubated for 5 days under anaerobic conditions. Established methods were used to identify anaerobic and aerobic micro-organisms. Numbers of micro-organisms were estimated semi-quantitatively by a selected group of trained laboratory workers. When micro-organisms were detected after one week of incubation time, culture results were scored as 'positive'. In 'negative' cultures, micro-organisms were not present after one week.

Statistical analysis

Statistical analysis was performed using SPSS-10 for PC. Differences between morphological scores of the epithelium, basal lamina and sub-mucosa obtained before sinus floor elevation surgery and three and nine months following elevation surgery were tested with the Friedman test for more than two related samples. Microbiologic outcomes were assessed applying the Wilcoxon signed ranks test for two related samples.

Results

Patients (Table 1)

Preoperative characteristics

Five out of 17 patients had a history of sinus related pathology. Two of them had a history of obstructive lung disease, two patients had a proven allergy for house

Table 1 Results of unilateral microbiologic culture (C), radiographic (X), and endoscopic (E) examination before surgery and three and nine months following elevation surgery. Preoperatively clearance compromised factors were anamnesticly present in patients 1-5, viz. COPD (patients 1, 2), allergy (patients 1, 4, 5), paranasal surgery (patient 1, 5) and cleft lip and palate (patient 3).

Patient	Side	Pre-operative			3 months			9 months		
		C	X	E	C	X	E	C	X	E
1	L	+	--	0	+	+	3	--	+	0
2	R	--	--	2	+	+	2	+	+	2
3	R	--	--	4	+	--	0	+	+	0
4	R	+	--	0	+	--	0	+	--	0
5	L	--	--	0	--	--	1	--	--	0
6	L	--	--	0	--	--	0	+	--	0
7	L	--	--	0	+	--	0	--	--	0
8	L	--	--	0	+	--	0	+	--	2
9	L	+	--	0	+	+	1	--	--	0
10	R	--	--	0	+	--	0	--	--	0
11	L	--	--	2	+	--	0	+	--	0
12	L	--	--	0	+	+	0	+	--	0
13	L	--	--	0	--	--	0	--	--	0
14	L	+	--	0	+	--	0	--	--	0
15	L	+	--	0	+	--	0	+	--	0
16	L	--	--	0	--	--	0	--	--	0
17	L	+	--	0	+	--	0	+	--	0

C: Culture score: negative --, positive +

X: Radiographic score: clear sinus --, mucosal thickening +

E: Endoscopic score: normal 0, hyperaemia 1, swelling 2, discharge 3, polyposis 4.

dust mites; one of them had undergone paranasal surgery some years before. One other patient had a history of cleft surgery.

Post-operative characteristics

Two weeks post-operatively, one patient suffered from severe maxillary sinusitis on the side that was not endoscopically evaluated. This patient did not have a history of sinus clearance compromising factors. Under general anaesthesia, a middle meatal antrostomy and endonasal ethmoidectomy were carried out to treat this complication. At the three months evaluation, some mild prickle-like sensations existed, while conventional radiographic evaluation showed opacity of the involved maxillary sinus. At the nine months evaluation, all complaints had disap-

peared, although radiography still showed opacity and atelectasis of the maxillary sinus.

At the three months post-operative evaluation, none of the other 16 patients showed symptoms or clinical signs of sinus pathology. Radiography (Waters' projection) showed post-grafting opacity of the maxillary sinus floor in all patients. In four patients (two of whom had a history of a compromised sinus clearance) thickening of the parietal maxillary mucosa was observed as well. Retention cysts of the maxillary sinus were observed in two other (non-compromised) patients.

Nine months post-elevation, none of the 17 patients had any clinical sign of maxillary sinusitis. In addition to the post-grafting opacity of the maxillary sinus, Waters' projection showed thickening of the parietal mucosa in three patients, all of them having a history of sinus clearance compromising factors. Retention cysts of the maxillary sinus were observed in the same two patients as reported for the three months evaluation.

Endoscopy (Table 1)

Preoperative characteristics

In 14 patients endoscopical unilateral examination showed a normal mucosa. In two patients mucosal swelling (grade 2) and in one patient antral polyposis (grade 4) were present. Two of these three patients were known with a history of a compromised sinus clearance.

Postoperative characteristics

At the three months follow-up, unilateral endoscopic evaluation showed a mucosal divergent aspect (grade 1 or more) in four patients. Three of these patients had a history of a compromised clearance. A grade 0 (normal) endoscopic score was found in two patients who showed preoperatively a deviant score.

Nine months after elevation surgery, swollen mucosa (grade 2) could be detected in two patients. In one of them, this grading had also been observed preoperatively as well as at the three months endoscopic evaluation.

Light microscopy

Pre-elevation

With regard to the morphological aspect, LM examination showed a healthy ciliated aspect and normal thickness of the epithelium in all 14 patients with endoscopically normal (grade 0), as well as in the other three patients with endoscopically abnormal aspect (grade 2 and 4) of the maxillary mucosa (Figure 2A).

The mean goblet cell-ratio (number of goblet cells per 100 epithelial cells) was 20 ± 13.5 (95% confidence interval of difference 13.4-27.4). In most patients only a few (0-3) mononuclear cells (lymphocytes) per HPF were observed in the mucosa. The basal lamina was visible in one patient only. In the submucosa between 5 and 35 inflammatory cells per HPF (mostly lymphocytes) were detected (mean 17.4 ± 9.1 ; 95% confidence interval of difference 12.8-22.1). Submucosal glands were absent in most of the specimens. Thirteen patients showed the existence of areolar connective tissue. In four patients 'dense' connective tissue was found. None of the patients showed fibrosis.

Three months post-elevation

In comparison with the preoperative situation, the thickness and ciliated aspect of the epithelium had not changed (Figure 3A). However, there was a non-significant tendency that the mean goblet cell-ratio had increased (mean 28.0 ± 15.6 ; 95% interval of confidence 20.5-36.6). The basal lamina was thickened (i.e. clearly visible) in six of the 17 patients. The submucosal inflammatory response did not show a (significant) difference in number of mononuclear cells (mean 20.3 ± 10.8 ; 95% confidence interval 14.7-25.8). The number of blood vessels had not changed compared with the preoperative results. The connective tissue integrity did not show any difference compared with the preoperative findings and submucosal fibrosis was not observed.

Nine months post-elevation

Of all evaluated morphological parameters, only the goblet cell-ratio showed a significant increase compared with the pre-elevation data (mean 43.7 ± 24.7 ; 95% confidence interval 31.1-56.5). In none of the evaluated patients fibrotic connective tissue was found (Figure 3B).

Electron Microscopy

Pre-elevation

With SEM and TEM examination a normal ciliated epithelium and goblet cells with normal intercellular adherence with desmosomes interconnecting the cells were observed preoperatively (Figures 3C, 3D).

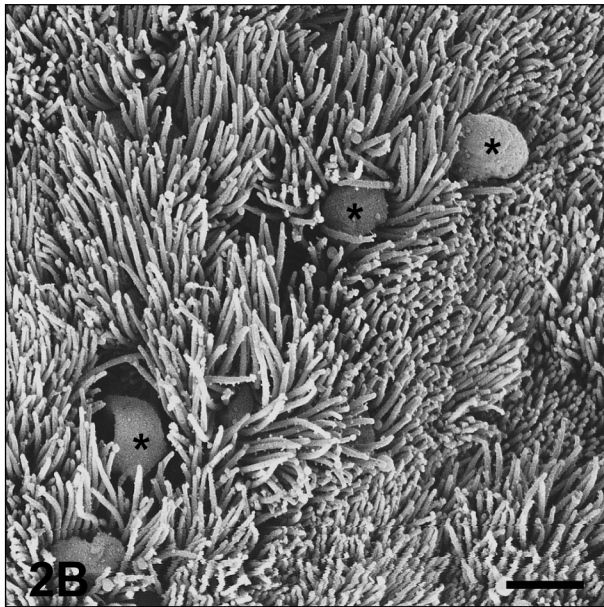
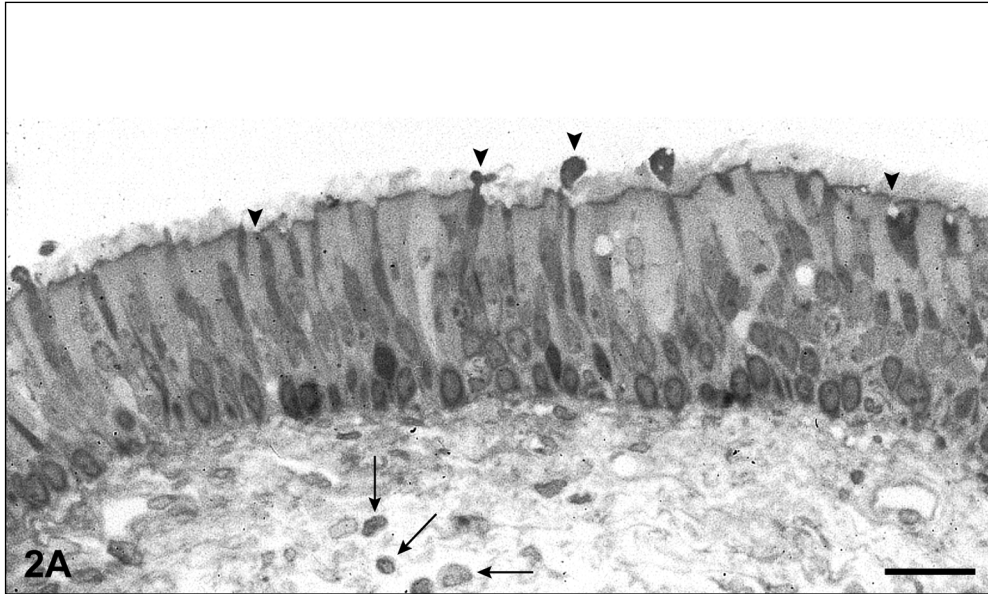


Figure 2

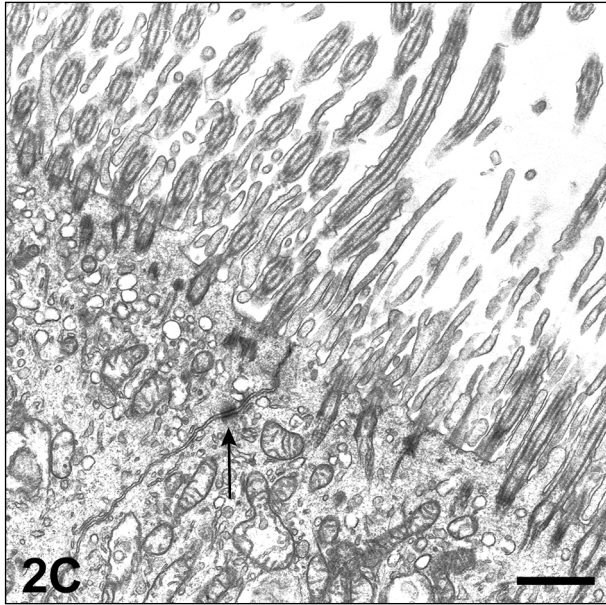
Histomorphological aspects of the antral mucosa pre-elevation.

A LM image of the maxillary sinus mucosa is showing a normal pseudostratified ciliated epithelium. A few goblet cells are present (arrowheads). In the submucosa a few inflammatory cells are visible (arrows). Submucosal glands are not found in this specimen. The submucosa consists of areolar connective tissue. (Toluidin blue staining; Bar = 45 μ m).

B SEM image showing a normal ciliated epithelium, with a few mucus producing goblet cells (asterisk). Bar = 2 μ m.

Three months post-elevation

The ciliated aspect of the epithelial surface showed extensive presence of microvilli as well. This surface aspect was not found in the preoperative specimen. An

**Figure 2 (Continued)**

Histomorphological aspects of the antral mucosa pre-elevation.

C TEM image of two ciliated cells showing a normal cell adhesion with desmosome interconnection (arrow), and an abundance of mitochondria. Bar = 0,8 μ m.

increase in number of goblet cells and presence of (branched) microvilli was observed (Figures 3E, 3F). The 9/2 aspect of the cilia (nine pairs of peripheral microtubules, around two central microtubules) showed findings of occasional abnormalities of this 9/2-architecture. Especially compound cilia (cilia consisting more than the normal '9/2' micro-tubular subunits) were noticed. This deviated aspect of the 9/2-architecture has previously been described in healthy respiratory mucosa and in bronchial epithelium of heavy smokers (Rossman et al. 1984).

Nine months after elevation

Both the TEM and SEM evaluation showed normal ultrastructural aspects of the epithelium and submucosa (Figures 3G, 3H).

Bacteriology (Table 2)**Pre-operative observations**

Evaluation of the cultures taken prior to the elevation procedure revealed that 11 out of 17 maxillary sinus cultures were negative, two samples showed polybacterial growth and in four cultures a monoculture of bacteria was found.

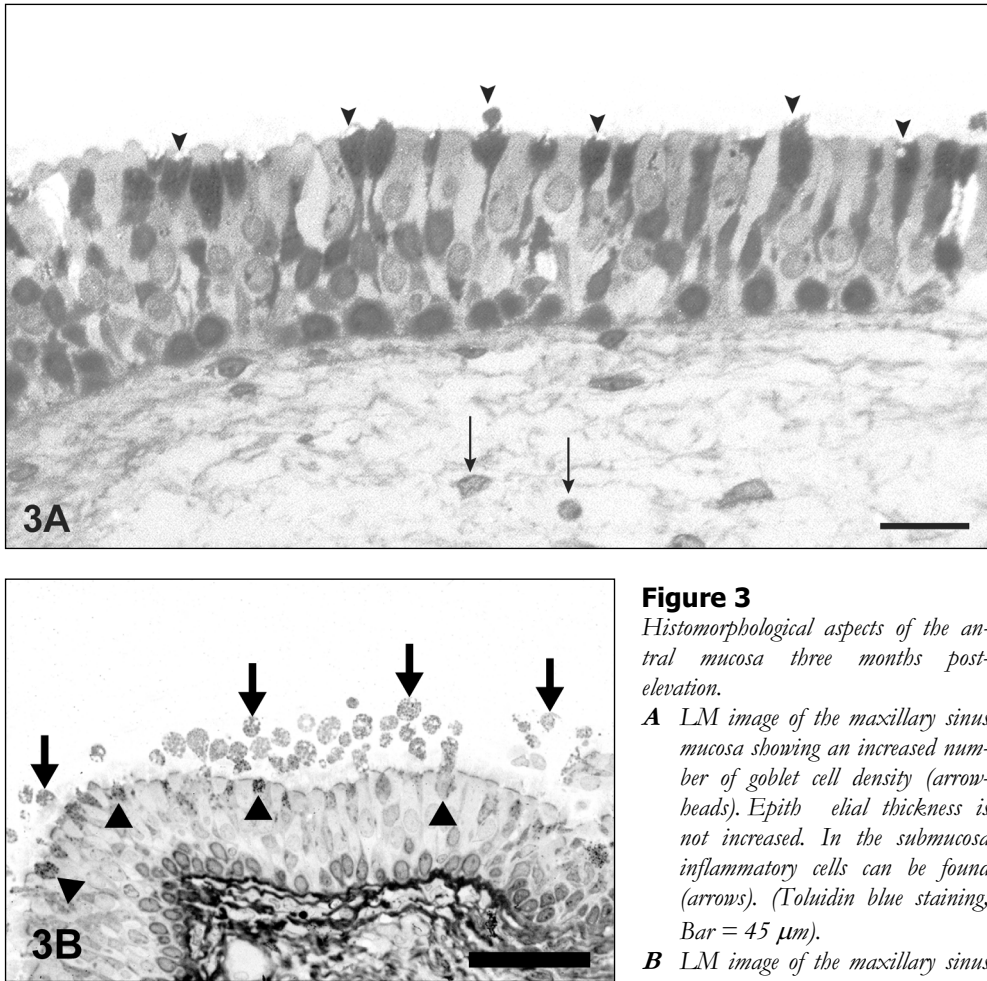


Figure 3

Histomorphological aspects of the antral mucosa three months post-elevation.

A LM image of the maxillary sinus mucosa showing an increased number of goblet cell density (arrowheads). Epithelial thickness is not increased. In the submucosa inflammatory cells can be found (arrows). (Toluidin blue staining; Bar = 45 μ m).

B LM image of the maxillary sinus mucosa nine months post-elevation showing an increase of the goblet cell ratio. The submucosa shows a normal aspect without abundant fibrotic connective tissue. (Arrowheads pointing to goblet cells; arrows are pointed to mucus. (Bar = 26 μ m)

Three months post-elevation observations

Three cultures were found to be negative. In seven cultures a polybacterial growth was found. In seven other cultures monobacterial growth was detected. Thus,

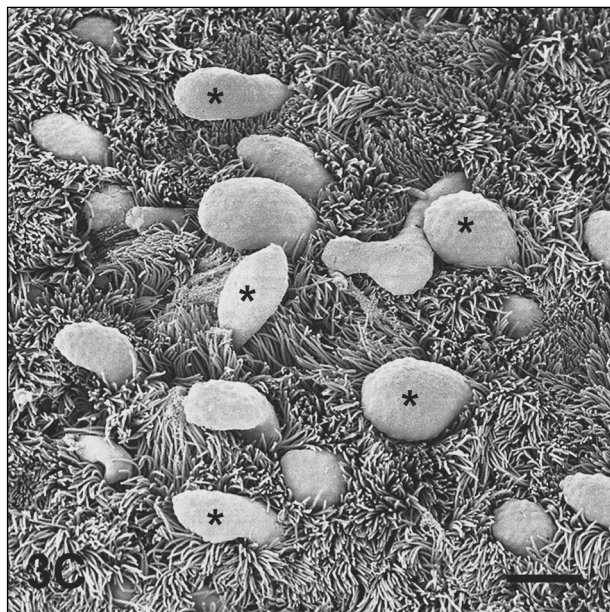
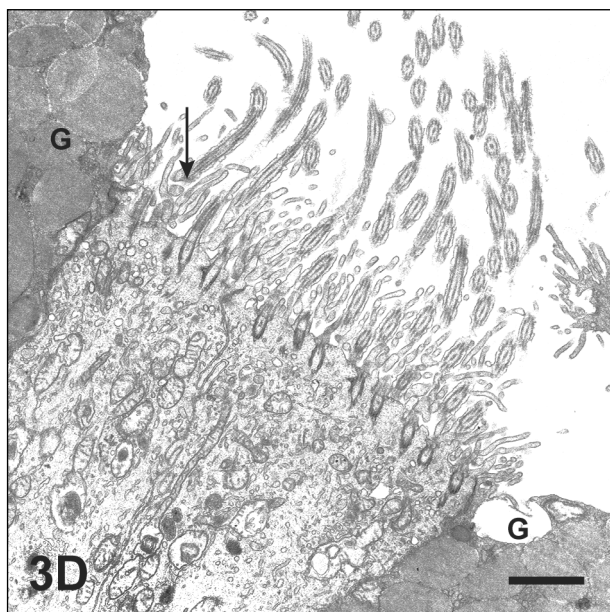


Figure 3 (continued)

Histomorphological aspects of the antral mucosa three months post-elevation.

C SEM image, showing an increased number of mucous producing goblet cells (asterisk). Bar = 4 μ m.

D TEM image showing a ciliated epithelial cell between two goblet cells (G). Some branched microvilli (arrow), are present on the surface of the ciliated cell. Bar = 2,5 μ m.



when compared with control sinus, there was a significant increase in positive culture results three months after elevation ($p < 0.05$).

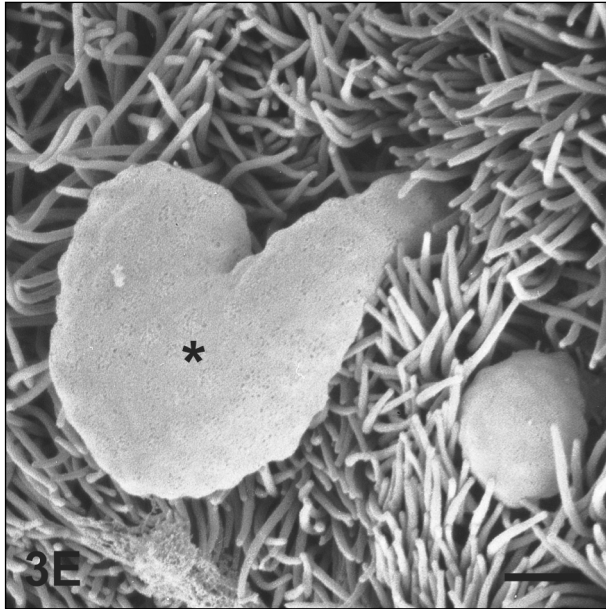
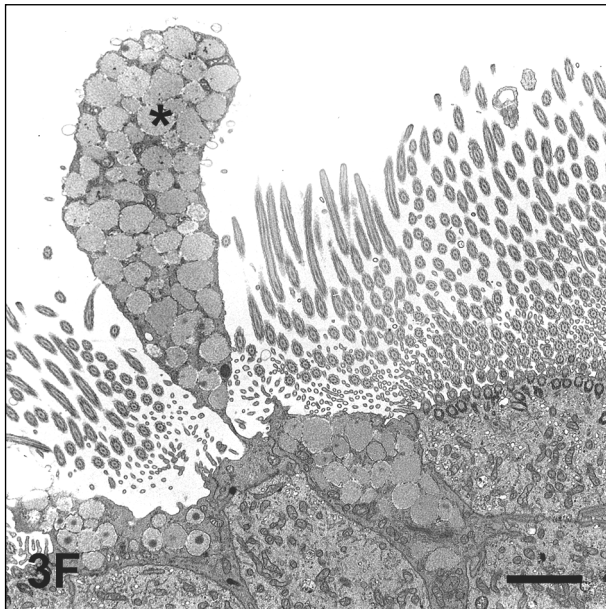


Figure 3 (continued)

Histomorphological aspects of the antral mucosa three months post-elevation (continued).

E TEM image showing release of mucus producing goblet cell (asterisk). Bar = 1,6 μm .

F TEM image showing release of mucus producing goblet cell (asterisk). Bar = 1,6 μm .



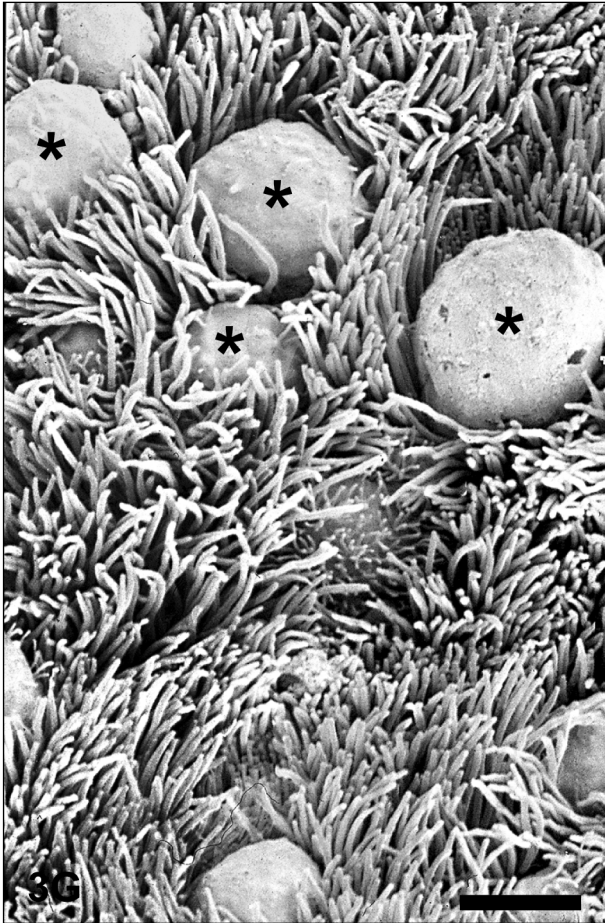


Figure 3 (continued)

Histomorphological aspects of the antral mucosa three months post-elevation (continued).

G SEM image nine months post-elevation showing mucus producing goblet cells (asterisk) surrounded by healthy ciliated cells. (Bar = 10 μ m)

H TEM image nine months post-elevation showing a normal aspect of the epithelium (E), basal lamina (Bm) and submucosa (Sm). (Bar = 4,4 μ m)

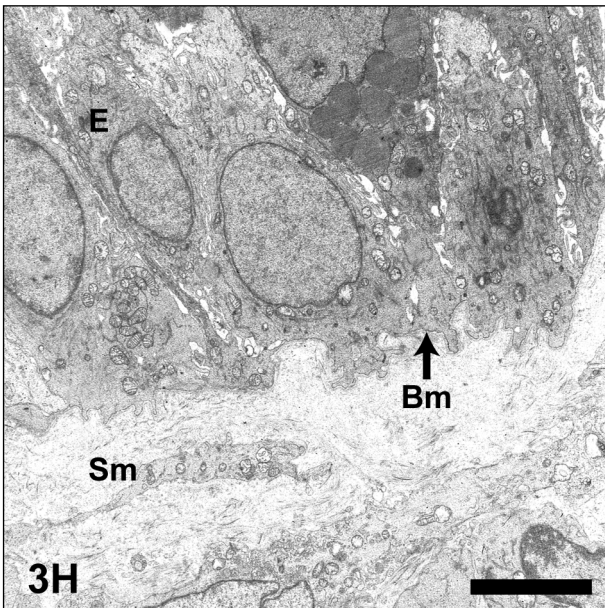


Table 2 *Culture results of sinus aspirates.**

Side	Patient no	Pre-elevation	At three months	At nine months
L	1	CNS	H. infl.	Negative
R	2	Negative	B. frag.	Gram+ cocci
R	3	Negative	CNS, Str. Vir.	Proteus
R	4	CNS	CNS, Str. vir., Proteus	Proteus, Gram+/-cocci
L	5	Negative	CNS, E coli, S. aur.	Negative
L	6	Negative	Negative	S. aur.
L	7	Negative	CNS	Negative
L	8	Negative	CNS, Str. Vir.	H. infl. Str. vir., CNS
L	9	CNS	M. cath.	Negative
R	10**	Negative	B. frag., Fusobact.	Negative
L	11	Negative	CNS, Str. vir.	CNS
L	12	Negative	CNS, Str. vir.	CNS
L	13	Negative	Negative	Negative
L	14	Anaer.	Anaer.	Negative
L	15	Str. vir., Aerob.	CNS	Proteus
L	16	Negative	Negative	Negative
L	17	Klebsiella, Str. vir., CNS	CNS	CNS

* meaning of abbreviations:

CNS	Coagulase-negative staphylococci
H. infl.	Haemophilus influenzae
B. frag.	Bacteroides fragilis
Str.vir.	Streptococcus viridans
E. coli	Escherichia coli
S. aer.	Staphylococcus aureus
M. cath.	Moraxella catarrhalis
Anear./Aerob.	Anaerobic/Aerobic bacteria
Fusobact	Fusobacteriae
Klebsiella	Klebsiella pneumoniae
Proteus	Proteus mirabilis

**Patient developed chronic maxillary sinusitis at the contralateral, not endoscopically examined, left side.

Nine months post-elevation observations

At implant insertion, eight out of 17 cultures were found to be negative. In two cultures polybacterial growth was found, while in seven other cultures monobacterial growth was detected.

Discussion

This report is the first prospective evaluation of sinus physiology in patients, who had no signs of maxillary sinusitis prior to sinus floor elevation surgery, using autogenous bone grafts. It became clear that only negligible mucosal reactions were seen after elevation surgery of the maxillary sinus floor. Only one patient developed purulent maxillary sinusitis that needed functional endoscopic surgery.

The rather low complication rate is somewhat surprising. A transient or persisting effect on the ciliated antral mucosa could be expected as result of maxillary sinus floor elevation surgery raising the maxillary membrane. Especially, when the maxillary sinus is filled up with blood, delay of the maxillary sinus clearance is thought to occur, because it is generally assumed that a reduction of the patency of the ostio-meatal unit is a potential risk for the development of sinusitis. The results of this study, however, suggest that the maxillary sinus mucosa is capable to adapt adequately to the changes induced by elevation procedure, especially in cases of non-compromised sinus clearance (Stammberger 1986; Jensen et al. 1998).

Endoscopic examination revealed that the surgical elevation procedure resulted in mild changes to maxillary mucous membrane in a few patients. These changes may even be the result of the physiologic dynamic course of the maxillary sinus mucosal activity as a function of the airway tissue defence system in humans (Kauffman and Tomee 1998). Postoperative swelling, as can be expected after sinus floor elevation surgery, may influence the mucociliary barrier function and increase its vulnerability. The three months post-elevation morphological examination revealed complete recovery of the maxillary sinus physiology in all patients but one. The existence of a mild inflammatory reaction, as observed by endoscopic evaluation, should be interpreted as a normal physiologic activity of the mucosal airway defence system. This is comparable to the diffuse mucosal reaction of the sinus mucosa that can be observed in healthy, non-operated human beings (Smith and Cable 1988; Kauffman and Tomee 1998).

Since bacterial cultures are used for microbiological examination of the maxillary sinus, many studies have been performed showing the presence of a wide variety of aerobic and anaerobic bacteria. In most cases the patients in these studies suffered from acute or chronic maxillary sinusitis. The microbiologic status of the maxillary sinus in healthy individuals was recently described (Jiang et al. 1999), and it appeared that the healthy maxillary sinus is not sterile, as was also confirmed in this study. The definition of a healthy maxillary sinus, however, varies in many studies. This definition was based on the anamnestic absence of pathology, on the

absence of radiographic signs of pathology or on the absence of endoscopic signs of pathology. The sinus fluid collecting technique of these studies is also quite variable, which makes reliable comparison of these results impossible. When dealing with microbiological studies, one should consider that patient selection, duration of disease, previous medical treatment, change of bacterial growth during disease, culture-transport and cultures-technique all are important influential factors (Verschraegen 1998). Comparison of culture results of sinus aspirates showed to be as good as results of specimen obtained by sinus endoscopy (Casiano et al. 2001). The increase of bacterial growth three months after sinus floor elevation might possibly be the effect of the surgical procedure, which affected the maxillary mucosal lining and especially the mucosal defence system. A (mildly) decreased sinus clearance probably facilitates the temporary presence of micro-organisms. Vascular injury following surgery, mucosal swelling, the presence of old blood and a decrease of the patency of the ostio-meatal unit might reduce the oxygen pressure in the sinus, resulting in an impaired sinus clearance (Aust and Drettner 1974). This environment possibly favours growth of (pathogenic) bacteria in the maxillary sinus (reduced colonisation resistance) as was found in this study three months postoperatively. In reverse, after recovery of the sinus the environment might be comparable with the preoperative situation.

Histomorphological examination of maxillary sinus mucosal biopsies of all serially inspected and assessed patients revealed only an increase in the mean number of goblet cells and submucosal inflammatory cells at the postoperative phase. Presence of discharge was not detected endoscopically during follow-up. The increase of the number of goblet cells might be related to the fact that the post-surgical environment (mucosal injury) favours their development, or favours the differentiation of ciliated and basal cells into goblet cells (Halama et al. 1990; Norlander et al. 1992; Toskala et al. 1995; Bravetti et al. 1998; Smith et al. 2001). The number of goblet cells could also be interpreted as an adaptation reaction of the sinus mucosa which development takes several weeks.

Maxillary sinus floor elevation surgery appears to have little influence on the histological characteristics of the sinus mucosal membrane and on maxillary sinus physiology. The mild histopathological changes found probably reflect a diffuse expression of the dynamic course of the mucosal airway defence system and are of limited importance. Based on the results of this prospective study, it can be concluded that a maxillary sinus floor elevation with autogenous bone is a well-established procedure with only minimal effects on the maxillary sinus physiology not leading to manifest pathology.

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